Original Article

Dietary exposure to essential and potentially toxic elements for the population of Hanoi, Vietnam

Helle Marcussen PhD[1], Bodil H Jensen MSc[2], Annette Petersen MSc[2], Peter E Holm PhD[1]

[1]*Department of Plant and Environmental Sciences, Faculty of Science, University of Copenhagen, Frederiksberg C, Denmark*
[2]*Department of Food Chemistry, National Food Institute, Technical University of Denmark, Søborg, Denmark*

Knowledge of the dietary intake of essential and toxic elements in fast-developing Southeast Asian countries such as Vietnam is limited. Iron and Zn deficiency in Asia is a well-known problem and is partly due to rice constituting a major part of the diet. Dietary habits are changing and there is a need to build more knowledge so authorities can give dietary recommendations. The aim of this study was to determine the total dietary intake of essential and potentially toxic elements and to assess the nutritional quality and food safety risks of the average Hanoi diet. Twenty-two foods or food groups were identified and 14 samples of each food group were collected from markets and/or supermarkets in the period 2007-2009. Water spinach, water dropwort, watercress, water mimosa and pond fish are typically produced in wastewater-fed systems. Therefore, these samples were collected both at markets and from wastewater-fed production systems. The results showed little or no risk of toxic elements from the Hanoi diet in general. Further, element contributions from wastewater-fed products were low and does not seem to constitute a problem with respect to potentially toxic elements. A comparison of the average Hanoi dietary intake of essential elements to required intakes shows that the Hanoi diet is sufficient in most elements. However, the diet may be insufficient in Ca, Cr, Fe, K and possibly Zn for which dietary diversification of biofortification might provide solutions.

Key Words: essential elements, toxic elements, dietary intake, diet survey, Hanoi

INTRODUCTION

Rapid development, growing populations, as well as increasing urbanization and food demand in Southeast Asia combined with the re-use of wastewaters for peri-urban food production constitute a potential food safety risk. The knowledge of dietary intake of essential and toxic elements in Southeast Asian countries such as Vietnam is limited. Vietnam has been undergoing an economic transition period due to political and economic reforms in the 1980s. The economic growth has resulted in improved nutritional status with higher energy intakes, a reduction in the prevalence of underweight, and increased average height and weight of the Vietnamese population, though part of the poor population still suffers from a deficient diet.[1-3] A number of studies have shown that anemia is a health problem in Vietnam among women and children and that it is at least partly linked to iron deficiency.[4-7] Traditionally, rice constitutes the major part of the diet in Vietnam.[8] Polished and parboiled rice is known to have a low content of essential elements such as iron and zinc, and the predominance of rice as a staple food is considered to be one of the main reasons for the high degree of zinc and iron deficiency in Asia.[9,10] Karunaratne *et al.* found zinc (Zn) and iron (Fe) concentrations for paddy rice to range between 0.095-0.233 and 0.034-0.106 mg kg^{-1} dry weight (d.w.), respectively with the lowest concentrations for the most processed rice.[10] A study of the dietary intake of micronutrients in South Vietnam showed a deficiency of Fe, calcium (Ca), phosphorus (P), potassium (K) and magnesium (Mg) in rural school girls.[11]

Typically, diet is the major human exposure route of toxic elements such as heavy metals.[12] Food products are contaminated with toxic elements, which may be of both natural and anthropogenic origin, through exposure to air, soil and water. There is a great demand for daily delivery of fresh vegetables and other aquatic products in the major cities in Asia, which is why production of such foods takes place in the peri-urban areas.[13] The production benefits from the use of urban wastewater as a cheap and readily available source of water and nutrients. Wastewater is discharged from households, hospitals and industries after little or no treatment; it is then transported out of the city in rivers or sewerage systems.[14] In the peri-urban areas the wastewater is pumped into the production

Corresponding Author: Dr Helle Marcussen, Department of Plant and Environmental Sciences, Faculty of Science, University of Copenhagen, Thorvaldsensvej 40 6th floor, 1871 Frederiksberg C, Denmark.
Tel: +45 35332413; Fax +45 35332398
Email: hma@life.ku.dk; marcussen.helle@gmail.com
Manuscript received 24 April 2012. Initial review completed 16 October 2012. Revision accepted 18 December 2012.
doi:10.6133/apjcn.2013.22.2.06

systems on a daily to weekly basis.[13,15] In Hanoi food products typically produced in wastewater-fed systems are vegetables such as water spinach, watercress, water mimosa and water dropwort and pond fish such as tilapia, common carp, silver carp, mud carp and black carp. Household wastewater, especially industrial wastewater, is known to contain a range of toxic elements and studies of the wastewater receiving rivers in Hanoi have documented accumulation of a range of highly toxic elements such as cadmium (Cd).[16] There has been some concern that the use of untreated wastewater may result in high toxic element concentrations in the Hanoi diet.

The objective of the present study was to determine the total dietary intake of essential and potentially toxic elements and to assess the nutritional quality and food safety risks of the average Hanoi diet. Furthermore, foods or food groups responsible for the majority of the potentially toxic element intake were identified and the intake from wastewater-fed vegetables and aquatic products was assessed.

MATERIALS AND METHODS

Selection of dietary consumption data

Few recent studies of dietary consumption in Vietnam are available. The Vietnam General Statistical Office has studied dietary consumption in Vietnam in two studies from 1992-1993 and 1997-1998 respectively.[2] In these studies dietary consumption was investigated though a twelve-month recall study, which may give reasonable estimates of the general consumption in Vietnam. The National Institute of Nutrition carried out a 24-hour recall food survey of Vietnamese people in eight different regions in 2000.[8] Since the aim of the current study was to investigate the dietary intake of residents of Hanoi, it was decided to use consumption data from a 24-hour diet recall study reporting consumption for 250 households in urban-Hanoi, carried out by The World Vegetable Center.[17] In this study households were interviewed three times during the year to cover the three distinct seasons which influence vegetable and fruit consumption. Each household reported the quantity of all individual food items they had consumed within the last 24 hours. The results were reported as the average of the three interviews after regrouping the food items into seven food groups: cereals, vegetables, fruits, meats, aquatic products, eggs and milk, and others. The food groups of vegetables and fruits were further divided into seven and three subgroups, respectively to give more detailed information as these foods were found to represent the main sources of diversity in food intake.[17] Data by Ali *et al.* were combined with information from an unpublished household food survey by the Research Institute for Fruits and Vegetables in 2002-2003, to obtain more detailed information about quantities of the different vegetables consumed and assumed that 2 L of drinking water is consumed per day as proposed by WHO.[17-19] The resulting average diet of people living in Hanoi divided into 22 food groups is presented in Table 1. This average diet was used for the col-

Table 1. Consumption data for people living in Hanoi

Food group	Consumption (g/day)	Commodities included
Cabbage[†,‡,§]	57.8	18.6% cauliflower, 18.6% broccoli, 18.6% Chinese cabbage, 18.6% common cabbage, 25.6% pac-choi
Water spinach[‡]	75	Water spinach
Cucurbits[‡]	13.3	38.4% Smooth loofah, 23.7% wax gourd, 20.9% bottled gourd, 38.4 pumpkin buds
Green beans[‡]	9.9	Green beans
Kohlrabi[‡]	16.3	Kohlrabi
Water mimosa[¶]	2	Water mimosa
Mixed vegetables[‡]	38.2	30.8% mustard, 28.8% tomato, 19.1% alliums, 12.3% ceylon spinach, 8.9% bamboo shoots
Water dropwort[¶]	2	Water dropwort
Summer fruit[†,§]	99.3	Equal amounts of water melon, mango, avocado, custard apple, guava, lychee, longan, cantaloupe melon, pineapple, peach, oranges, plum and lemon
Winter fruit[†,§]	75.2	Equal amounts of oranges, tangerines, grapefruits and apples
Watercress[¶]	2	Watercress
Dried pulses[†,§]	19.3	Equal amounts of mung and blanck bean
Bovine meat[‡,§,††]	18.9	Equal amounts sirloin, tenderloin, top sirloin and bottom sirloin
Pond fish[†,§,††]	25.3	Equal amounts of common carp, silver carp, Indian carp and tilapia
Pork meat[‡,§,††]	56.7	Equal amounts of shoulder butt, picnic shoulder, loin, side and ham
Pork offal[‡,§,††]	3.1	Equal amounts liver, kidney and heart of pork
Poultry[‡,§]	17.8	Equal amounts of duck, chicken and moscovy duck
Seafood[†,§,††]	25.3	Equal amounts of black tiger shimp, laying scad, mackerel, cuttlefish, squid
Eggs[†,§,††]	11	Equal amounts of hen and duck eggs
Milk[†,§,††]	22	Milk
Rice[‡,§]	303	Equal amounts of 3 different rice species
Total	894	
Drinking water[†††]	2000	Tap water

[†]The weight of average consumption of a food group was obtained from a 24 hour recall food survey conducted in Hanoi.[17]
[‡]The weight of average consumption of a food group or the relative consumption of each food commodity in a food group was determined from a 24 hour food survey conducted in Hanoi.[18]
[§]It was assumed that equal amounts of each food commodity in a food group were consumed.
[¶]Vegetables not among the 20 consumed in the highest amounts; a consumption of 2 g was assumed
[††]The relative content of each food commodity was calculated from the region's GEMS Food cluster diet.[20]
[†††]WHO assumes that the water consumption for adults is 2 L/day, though it is recognized that this may vary depending on climate, activity level and diet.[19]

lection of samples and the calculation of average element intake. For food groups for which only the total consumption was known, consumption of the different food items was estimated by assuming the same distribution between items as for the GEMS Food Cluster diet.[20] If, for example, a total of 75.6 g pork and bovine meat is consumed, the consumption of bovine meat is estimated to be 25% of the total. The presented average total daily diet (Table 1) contains 894 g of food, excluding drinking water. Ali *et al.* reported the average daily food consumption of Hanoi residents to be a total of 1129 g, showing that this study covers element intake from approximately 80% of a typical average diet.[17]

Collection, pre-treatment and analysis of food samples

The 22 food item groups presented in Table 1 were collected with 14 samples for each food group in the period 2007-2009. The food samples were collected at seven markets located in urban Hanoi from two booths at each market. Samples normally purchased at supermarkets were also collected at 14 supermarkets and samples normally purchased at both markets and supermarkets were collected from one booth at seven markets and seven supermarkets. As water spinach, water dropwort, watercress, and water mimosa are typically produced in wastewater-fed systems these were collected both at markets and from wastewater-fed production sites. Drinking water samples were collected from taps at seven markets and in seven households. The edible part of the collected foods was washed in distilled water. Wet samples (e.g. vegetables and meat) were homogenized in a kitchen blender with stainless steel knife blades. Dry samples (e.g. rice and pulses) were pulverized in an agate ball mill. All samples were freeze-dried, and the wet and dry weights were determined.

For each food sample, 0.25 g was digested in 6 ml conc. HNO_3 (Baker Instra-Analyzed) and 2 ml H_2O_2 (Baker Instra-Analysed) in a microwave assisted system (Multiwave 3000, Anton Paar GmbH). Drinking water samples were filtered through a 0.45 µm syringe nylon filter (Millipore) and acidified to 0.2% HNO_3. The total concentrations of 39 elements were determined by ICP-MS equipped with an octopole reaction chamber pressurized with helium or hydrogen to remove polyatomic interferences (Agilent 7500C, Agilent Technologies, Manchester, UK). External calibration was applied and drift within 10% was corrected for by recalibration with three standards for every 16 samples analysed. The limit of detection (LOD) was calculated as three times the standard deviation (SD) of a minimum of eight replicate analyses of the calibration blank (Table 2). Quality assurance was conducted by including blanks, a double determination and certified reference material in every digestion. The reference materials were: spinach NCS ZC73013 (China National Analysis Center for Iron and Steel, LGC Standards) and bovine muscle BCR no. 184 (Community Bureau of Reference, Commission of the European Communities). Concentrations of digestion blanks were below LOD or insignificant compared to sample concentrations, double determinations were acceptable and determined concentrations in reference materials were within 10% of the certified range (Table 2).

Dietary intake calculations

The total dietary intake of an element was calculated as the sum of the average element concentration times the average consumption of each food group, as given by the following formula.

$$\text{Total intake} = \sum_{1}^{i=n} C_i \times \text{consumption}_i$$

where "i" indicates a food group and "C" the average element concentration for the food group.

Two alternative calculations were carried out for the elements, which include samples with concentrations below the LOD. In the first calculation, element concentrations below the LOD were substituted with the value zero and in the second calculation, element concentrations below the LOD were substituted with the value of the LOD. The actual element intake is therefore somewhere between the two calculated values.

Assessment of food quality and safety

The food quality and safety risk assessment was carried out by comparing the average element intake with recommended dietary allowances (RDA) and the tolerable intake per kg body weight.[20-25] In the western world, a body weight of 60 kg is normally used in food safety assessments. However, this value is too high for the Vietnamese population. Khan *et al.* reported average body weights of adult Vietnamese in different age groups to range between 45-49 kg and 52-56 kg for women and men, respectively.[1] The overall average body weight for Vietnamese people is therefore about 50 kg for both men and women and this value was used in calculations in this study.

RESULTS

The average daily dietary intake of essential, non-essential and potentially toxic elements for the Hanoi population is given in Tables 3 and 4. With respect to the elements: Ba, Cd, Ce, Cu, Fe, K, Mg, Mn, Ni, P, Pb, Sr, V and Zn, there was a difference of less than 10% between intakes calculated by substituting the LOD with either zero or the value of LOD. However, for the elements: Ag, As, Be, Cr, Ho, La, Sb, Se, Sm, Tb, Tl, Tm, U, V and Yb, the calculation involving substitution of concentrations below the LOD with the value of the LOD resulted in intakes more than 100% higher than calculations in which the LOD was substituted with zero. The highest contribution of a single food or food group to the intake of the different elements is also given in Tables 3 and 4. This calculation was based on intake calculations where values below the LOD were substituted with zero and may therefore have underestimated the contribution of some elements.

Rice had the highest contribution of any food to the intake of 21 of the 39 determined elements Ag, Ba, Be, Cd, Ce, Cr, Dy, Er, Gd, Mg, Mn, Mo, Nd, Ni, P, Pb, Pr, Th, Y and Zn. Sixteen of these elements had an intake from rice that constituted more than 40% of the total intake (Tables 3 and 4). Intake of drinking water resulted in the highest intake of Ca, Li, Sb, Sc, Sr, U and V and consumption of dried pulses resulted in the highest intakes of K, La, Sm, Tm and Yb (Tables 3 and 4). Consumption of pork

Table 2. LOD and certified and measured concentration (mean±SD) for the reference materials spinach NCS ZC73013 and bovine muscle BCR no. 184.

	LOD		Spinach		Bovine muscle	
	µg/L	mg/kg	Certified mg/kg d.w.	Measured mg/kg d.w.	Certified mg/kg d.w.	Measured mg/kg d.w.
Ag	0.010	0.020		<LOD		
As	0.10	0.20	0.23±0.03	<LOD		
Ba	0.0053	0.011	9.0±0.8	9.13±1.65		
Be	0.0020	0.0040	0.017±0.002	0.019±0.009		
Ca	80	160	6600±300	6781±195		
Cd	0.0078	0.016	0.150±0.025	0.15±0.01	0.013±0.002	0.011±0.008
Ce	0.00069	0.0014	0.66±0.05	0.592±0.067		
Co	0.0081	0.016	0.22±0.03	0.24±0.03		
Cr	0.072	0.14	1.4±0.2	1.3±0.2		
Cu	0.040	0.081	8.9±0.4	9.94±4.84	2.36±0.06	2.18±0.23
Dy	0.00066	0.0013	0.041±0.008	0.035±0.004		
Er	0.00082	0.0016	0.017±0.003	0.017±0.003		
Fe	0.54	1.1	540±20	486±30	79±2	75±7
Gd	0.0011	0.0022	0.054±0.007	0.051±0.006		
Ho	0.0011	0.0022	0.0081±0.0017	0.008±0.002		
K	23	83	24900±11000	26697±923		
La	0.0013	0.0027	0.35±0.04	0.319±0.034		
Li	0.033	0.067	1.46±0.23	1.50±0.15		
Mg	0.80	1.6	5520±150	5716±135		
Mn	0.014	0.028	41±3	45.33±3.95	0.334±0.028	0.31±0.05
Mo	0.030	0.061	0.47±0.04	0.513±0.030		
Nd	0.0011	0.0022	0.28±0.03	0.261±0.025		
Ni	0.011	0.022	0.92±0.12	0.77±0.20		
P	16	31	3600±200	3635±444		
Pb	0.007	0.014	11.1±0.9	13.346±0.636	0.239±0.011	0.28±0.04
Pr	0.00031	0.00062	0.075±0.005	0.0702±0.0082		
Sb	0.0050	0.0099	0.043±0.014	0.038±0.005		
Sc	0.026	0.052	0.093†	0.07±0.08		
Sm	0.0011	0.0023	0.056±0.005	0.050±0.007		
Sr	0.0014	0.0029	87±5	77.725±5.720		
Tb	0.00036	0.0007	0.0072±0.0007	0.006±0.001		
Th	0.002	0.0046	0.114±0.019	0.106±0.020		
Tl	0.0027	0.0055	0.049†	0.049±0.006		
Tm	0.00027	0.00054	0.0031±0.0009	0.0024±0.0007		
U	0.002	0.0043	0.089±0.011	0.086±0.008		
V	0.0038	0.0076	0.87±0.23	0.741±0.043		
Y	0.0011	0.0022	0.20±0.04	0.167±0.011		
Yb	0.0021	0.0041	0.019±0.004	0.016±0.004		
Zn	0.019	0.039	35.3±1.5	35.69±1.52	166±3	156.33±9.47

†Values without calculated uncertainty are not certified and only for information purpose.

resulted in the highest Ho and Tb intakes. The highest intakes of As, Co, Cu and Fe came from the consumption of seafood, summer fruit, bovine meat, cabbage and poultry, respectively.

Discussion

Total element intake

The large difference between the calculated intakes of some elements depending on whether values below the LOD were substituted with zero or if the value of the LOD shows that the actual intake estimates for these elements were uncertain and were somewhere between the calculated values.

The high contribution of rice to element intake was found for elements that had both high and low concentrations in rice compared to the concentrations in other foods. Rice consumption resulted in the highest intake of Gd, Mg, Nd, Ni, Y and Zn, even though the concentrations in rice amounted to less than 10% of what was seen in the foods with the highest concentrations. Except for drinking water, rice was the food consumed in the highest amounts based on weight (Table 1). The intake of rice makes up 34% of the diet, which is the main reason for the high total element contribution from rice. Dried pulses contained the highest concentrations of 32 of the 39 determined elements and are therefore important for the total element intake even though dried pulses constituted only 2.2% (weight) of the collected diet. The highest intake of Ho and Tb comes from pork and Co intake comes primarily from summer fruit due to a combination of high consumption and relatively high concentrations in these particular foods. The relatively high intakes of As, Co, and Fe from seafood, bovine meat, cabbage and poultry, respectively were due to high element concentrations in these commodities compared to other foods.

Table 3. Average total dietary intake of essential elements in Hanoi with substitution of values below the LOD with zero and the value of the LOD. The relative deviation between total intake calculations. Percentage of total intake for the commodity with the highest intake contribution

	Total intake$_0$† mg/kg/day	Total intake$_{LOD}$‡ mg/kg/day	Relative deviation (%)	Highest contribution$_0$† % of total	
Ca	5.57	6.78	22	27	Drinking water
Co	$1.82·10^{-4}$	$2.75·10^{-4}$	51	33	Summer fruit
Cr	$5.95·10^{-4}$	$2.05·10^{-3}$	245	55	Rice
Cu	$6.14·10^{-2}$	$6.14·10^{-2}$	0	40	Cabbage
Fe	$1.63·10^{-1}$	$1.74·10^{-1}$	6	22	Poultry
K	33.8	33.8	0	14	Dried pulses
Mg	4.07	4.06	0	18	Rice
Mn	$8.37·10^{-2}$	$8.37·10^{-2}$	0	56	Rice
Mo	$6.86·10^{-3}$	$7.88·10^{-3}$	15	72	Rice
P	14.1	14.1	0	33	Rice
V	$8.09·10^{-5}$	$1.98·10^{-4}$	145	35	Drinking water
Zn	$1.80·10^{-1}$	$1.80·10^{-1}$	0	49	Rice

LOD: Limit of detection.
†Commodity concentrations below the LOD were replaced by the value zero in intake calculations.
‡Commodity concentrations below the LOD were replaced by the value of the LOD in intake calculations.

Table 4. Average total dietary intake of non-essential and potential toxic elements in Hanoi with substitution of values below the LOD with zero and the value of the LOD. The relative deviation between total intake calculations. Percentage of total intake for the commodity with the highest intake contribution

	Total intake$_0$† mg/kg/day	Total intake$_{LOD}$‡ mg/kg/day	Relative deviation (%)	Highest contribution$_0$† % of total	
Ag	$4.64·10^{-5}$	$2.53·10^{-4}$	445	77	Rice
As	$1.29·10^{-3}$	$4.62·10^{-3}$	258	59	Seafood
Ba	$1.48·10^{-2}$	$1.48·10^{-2}$	0	29	Rice
Be	$5.03·10^{-5}$	$1.05·10^{-4}$	109	70	Rice
Cd	$6.81·10^{-4}$	$7.00·10^{-4}$	3	90	Rice
Ce	$9.54·10^{-5}$	$9.83·10^{-5}$	3	48	Rice
Dy	$2.25·10^{-5}$	$2.68·10^{-5}$	19	78	Rice
Er	$1.55·10^{-5}$	$2.35·10^{-5}$	52	84	Rice
Gd	$1.56·10^{-5}$	$2.44·10^{-5}$	57	71	Rice
Ho	$8.63·10^{-6}$	$6.07·10^{-5}$	603	36	Pork
La	$4.02·10^{-5}$	$9.77·10^{-5}$	143	22	Dried pulses
Li	$2.85·10^{-4}$	$5.18·10^{-4}$	82	60	Drinking water
Nd	$2.55·10^{-5}$	$3.68·10^{-5}$	45	23	Rice
Ni	$4.02·10^{-3}$	$4.03·10^{-3}$	0	42	Rice
Pb	$5.39·10^{-4}$	$5.44·10^{-4}$	1	39	Rice
Pr	$1.16·10^{-5}$	$1.83·10^{-5}$	58	44	Rice
Sb	$3.35·10^{-5}$	$1.77·10^{-4}$	429	85	Drinking water
Sc	$1.22·10^{-5}$	$4.52·10^{-4}$	3600	52	Drinking water
Sm	$3.68·10^{-6}$	$2.82·10^{-5}$	666	20	Dried pulses
Sr	$2.00·10^{-2}$	$2.00·10^{-2}$	0	34	Drinking water
Tb	$1.48·10^{-6}$	$1.78·10^{-5}$	1099	28	Pork
Th	$5.07·10^{-5}$	$7.76·10^{-5}$	53	66	Rice
Tl	$2.77·10^{-5}$	$8.39·10^{-5}$	202	24	Water spinach
Tm	$1.87·10^{-6}$	$1.22·10^{-5}$	553	35	Dried pulses
U	$1.29·10^{-5}$	$6.42·10^{-5}$	398	53	Drinking water
Y	$5.15·10^{-5}$	$5.63·10^{-5}$	9	60	Rice
Yb	$1.24·10^{-5}$	$6.59·10^{-5}$	433	32	Dried pulses

LOD: Limit of detection.
†Commodity concentrations below the LOD were replaced by the value zero in intake calculations.
‡Commodity concentrations below the LOD were replaced by the value of the LOD in intake calculations.

Nutritional value of the diet

Dietary reference intake values (RDI) for Vietnamese people in the form of recommended dietary allowances (RDA) have been developed by the Vietnamese National Institute of Nutrition for selected essential elements (Table 5).[21] However, the Vietnamese RDAs do not contain recommendations for Cr, Cu, K, Mn and Mo. Therefore RDI values developed by the Food and Nutrition Board, Institute of Medicine, United States National Academy of Sciences, were applied in this food quality assessment of the Hanoi diet for these elements (Table 5).[22] A comparison of the average Hanoi dietary element intakes to RDI values shows that the Hanoi diet is fully sufficient in Cu, Mg, Mn, Mo and P (Table 5). However, the diet is insufficient in Ca, Cr, Fe and K and residents of Hanoi should supplement their diets with these elements. Diets in Asia are known to be low in Zn and Fe because polished rice constitutes a large part of the diet.[8-10] Rice consumption

Table 5. Dietary reference intakes and calculated coverage of dietary reference intake of selected elements for the Hanoi diet. Values below the LOD was substituted with zero for a worst case scenario

	RDI mg/person/day	Coverage of RDI_0[†††] %
Ca	1000[†]	33
Cr	35/25[‡]	0.1/0.1
Cu	0.9[§]	410
Fe (men/women)	13.7/29.4[†]	71/33
K	4700[‡]	43
Mg	205[†]	119
Mn	2.3/1.8[‡]	218/279
Mo	0.045[§]	914
P	700[†]	121
Zn[¶]	7[†]	154
Zn[††]	14[†]	77

LOD: Limit of detection, RDI: Dietary reference intake
[†]Vietnamese recommended dietary allowances (VN-RDA).[21]
[‡] US adequate intakes (AI), AI values are believed to cover the needs of healthy individuals but have less data foundation than RDA values.[22]
[§]US recommended dietary allowances (US-RDA).[22]
[¶]Recommended dietary allowances of Zn for food with moderate Zn bioavability.
[††]Recommended dietary allowances of Zn for food with low Zn bioavability.
[†††]Commodity concentrations below the LOD were replaced by the value of zero in intake calculations.

contributed to 49% of the daily Zn intake whereas only 30% originated from animal products such as poultry, seafood, pond fish, eggs, bovine meat and pork. The availability of Zn from the diet depends very much on the food consumed. Even though plants may have as high a content of Zn as animal products, Zn bioavailability in plants may be restricted due to the content of phytic acid (PA).[10,26,27] The World Health Organization categorized the potential availability of zinc in diets according to the PA:Zn ratio in foods; a ratio <5 indicates a high Zn uptake, a ratio of 5-15 indicates a moderate uptake and a ratio of >15 indicates a low uptake.[28] Karunaratne *et al.* investigated the PA:Zn ratios of different rice species with different pre-treatments and found most to be >15 and a few between 5-15.[10] Accordingly, the Zn bioavailability of the Hanoi diet can be expected to be low to moderate and the actual Zn intake from the Hanoi diet can be estimated to be in the range of 77-154% of the required amount, depending on actual bioavailability (Table 5).

The Hanoi diet results in an intake of only about one third of the required amount of Fe for women and 71 to 76% for men (Table 5). The main contribution to Fe intake was poultry, dried pulses and rice, which provided 22, 15 and 12% of the total intake, respectively. Rice had the third lowest Fe concentration of all foods, containing only 3% of the Fe concentration in poultry, which was the commodity with the highest Fe concentration. This confirmed that the high rice consumption constituted a problem with respect to Fe intake as it reduced the possible intake of other foods with higher iron content. Several studies have shown a high prevalence of anemia and iron deficiency in the Vietnamese population and anemia seems at least partially to be linked to iron deficiency.[5,6,11] Most of these studies focused on anemia and iron deficiency in children since they can have severe consequences such as retarded psychomotor development, impaired cognitive function and growth retardation.[4,7,11] However, Nhien *et al.* found 30% of a studied adult Vietnamese population to suffer from anemia, whereas Pasricha *et al.* studied 349 non-pregnant Vietnamese women and found that 38% and 23% suffered from anemia and iron deficiency, respectively.[5,6]

As discussed above, the Hanoi diet is deficient in Ca, Cr, Fe, K and maybe Zn. A comparison with total diet studies carried out in other countries is made in table 6. The daily dietary intake of Ca in Hanoi is low compared to other countries and also in the lower range of Ca intakes previously observed in Asia. The Cr intake is low compared to what had previously been seen for Asia but similar to intakes in Sweden and higher than intakes in the United States (Table 6). Iron and Zn intakes are within the range of what have been observed for other countries, and K intakes are in the lower ranges. However, the reported values are given as intake per person per day and considering that the bodyweight of an average person from Hanoi is lower that persons from the western world slightly less of these elements may be needed by the Hanoi population.

The Hanoi diet was found to be sufficient in Cu, Mg, Mn, Mo and P. Comparison with studies from other countries show that the intake of Mg and Mn are within the normal range, P intakes are slightly low compared to intakes in the United States, and Cu and Mo intakes are about a factor 3 higher that what is seen in other countries (Table 6). Cobalt intakes in Hanoi are similar to other countries except for Northern Italy which had higher intakes and V intakes were also lower than intakes in Northern Italy (Table 6).

Risk assessment of the diet

Tolerable intake reference values (TIRV) have been developed by the Codex Alimentarius Commission, U.S. National Academy of Science and WHO (Table 7). Provisional tolerable intake (PTI) values establish the acceptable level of a toxin that can be ingested. The provisional maximum tolerable intake (PMTI) and the tolerable upper intake levels (UL) establish the maximum intake of a nutrient or a non-cumulative contaminant that is likely to pose no health risk.

There is no concern with regard to toxic or harmful intakes of Ca, Cu Fe, Mg, Mn, Mo, Ni, P, U, V and Zn from the Hanoi diet (Table 7). The dietary intake of Cd amounts to 68-70% of the tolerable intake. As long as the population is not exposed to other significant sources of Cd such as smoking, intake from the diet can be considered safe. It is recommended that developments in Cd intakes be monitored in the future especially considering that rice consumption used in the calculations is the average amount and therefore some individuals will be exposed to higher Cd intakes. Ninety percent of the Cd intake is due to rice consumption (Table 4). Cadmium concentrations in rice samples varied between 0.03-0.22 mg/kg and the average concentration was 0.1 mg/kg. The

Table 6. Daily dietary intake of essential elements in international total diet studies given as µg $(person*day)^{-1}$ (without brackets) and µg $(kg\ body\ weight * day)^{-1}$ (in brackets)

Study	Ca	Co	Cr	Cu	Fe	K	Mg	Mn	Mo	P	V	Zn	Reference
Hanoi 2007-2009	278500 (5570)	9.10 (0.182)	29.7 (0.595)	3070 (61.4)	8150 (163)	1690000 (33800)	203500 (4070)	4185 (83.7)	343 (6.86)	705000 (14100)	4.045 (0.0809)	9000 (180)	Present study
United Kingdom 2006	-	-	(0.28-0.37)	(17.23)	-	-	-	(67)	(1.61-1.64)	-	-	(140.7)	29
Bombay 1991-1994	-	-	-	1477.75	-	-	-	-	-	-	-	10529	30
Tokyo 2000	-	-	-	784	-	-	-	2720	131	-	-	6750	31
Japan 2002	-	-	-	1150	-	-	-	-	-	-	-	-	32
Sweden 1999	1110000	11	25	1150	9200	3320000	285000	3500	-	-	-	11300	33
Asia 1995	220000-720000	9.6-17.9	59.9-224	870-2170	6600-31400	1040000-2700000	140000-460000	2830-10540	-	-	-	4340-13500	34
United States 1991-1996	512000-796000		3.5-5.2	-	9000-13900	1853000-2683000	184000-262000	1880-2660	-	889000-1392000	-	7600-12700	35
Northern Italy 2004	-	29	-	1140	11000	-	-	1380	79.6	-	12.2	12000	36
France	721000	7.53	76.9	980	-	-	224000	2310	138	-	-	8660	37

Table 7. The tolerable intake reference values (TIRV) and calculated intake of potentially toxic elements from the Hanoi diet relative to the TIRV with substitution of values below the LOD with zero and the value of the LOD

	TIRV	Intake relative to $TIRV_0$[†††] %	Intake relative to $TIRV_{LOD}$[††††] %
As (mg (kg·day)$^{-1}$)	0.003[†]	43	154
Ca (mg day^{-1})	2000/2500[‡]	17	20
Cd (mg (kg·day)$^{-1}$)	0.001[§]	68	70
Cu (mg (kg·day)$^{-1}$)	0.5[¶]	12	12
Fe (mg (kg·day)$^{-1}$)	0.8[¶]	20	22
Mg (mg day^{-1})	350[‡]	70	70
Mn (mg day^{-1})	11[‡]	46	46
Mo (mg day^{-1})	2[‡]	21	24
Ni (mg (kg·day)$^{-1}$)	0.012[††]	33	33
P (mg day^{-1})	3000/4000[‡]	21	21
Pb (mg (kg·day)$^{-1}$)	0.0035[§]	15	15
U (mg (kg·day)$^{-1}$)	0.6[§]	0	0
V (mg day^{-1})	1.8[¶]	1	1
Zn (mg (kg·day)$^{-1}$)	1[¶]	18	18

TIRV: Tolerable intake reference value, LOD: Limit of detection
[†]Benchmark doses for 0.5% increased risk of lung cancer by inorganic As intake.[25]
[‡]Tolerable upper intake levels (UL).[23]
[§]Provisional tolerable intake.[24]
[¶]Provisional maximum tolerable intake (PMTI).[24]
[††]Provisional tolerable intake.[19]
[†††]Commodity concentrations below the LOD were replaced by the value of zero in intake calculations.
[††††]Commodity concentrations below the LOD were replaced by the value of the LOD in intake calculations.

Codex Alimentarius Commission set a maximum level of 0.2 mg/kg for Cd in rice, which means that the average concentration in rice is acceptable, but some samples have high concentrations. Changes in the diet with respect to rice consumption can have a large influence on the Cd intake as only pork offal had similar high Cd concentrations while all other food samples had less than 40% of the Cd concentration found in rice. Comparison with total diet studies from other countries show the intake of Cd in Hanoi is high except for the United Kingdom where similar Cd intakes would be in the medium range (Table 8).

The calculated dietary As intake depends very much on the value used to substitute the LOD and it ranges between 43-154% of the tolerable intake (Table 7). The toxicity of As depends on its speciation; inorganic forms are much more toxic than organic forms and the PTI only concerns inorganic As.[25,44] It is known that the content of inorganic As compared to total As is normally below one percent in seafood whereas terrestrial products may contain from a few percent to 100% inorganic As.[45] As seafood is the main source of As in this study it is very unlikely that intake of As constitutes a food safety problem. Also Cr toxicity depends on its speciation. Cr is found mainly in the Cr(III) and Cr(VI) valency states with characteristics that range from being an essential trace element with is thought to be important in glucose metabolism to being a genotoxic carcinogen. As crops are known to have detoxifying mechanisms to reduce Cr(VI) to Cr(III) combined with the low Cr diet it is unlikely that the intake of Cr constitutes a food safety problem.

No TIRV has been developed for Tl. However, the human average dietary intake appears to be less than 5 µg/day, which constitutes no health threat.[46] In this study the average daily Tl intake was 1-4 µg. It is therefore assumed that the thallium intake does not constitute a food safety problem.

The dietary intake of non-essential and potentially toxic elements in Hanoi compare to other countries were low to medium for As, and within observed ranges for Pb, Sb, Sr and U (Table 8). The Ni intake was two times higher than intakes in Sweden and France but lower than intakes in Northern Italy. The Hanoi intakes of Ba, Be and Tl were higher than what have been observed in other studies whereas Ce, Li and Rb concentrations were lower. The foods typically produced in wastewater-fed systems contributed little to the total intake of the PTEs As, Cd Cu, Ni, Pb, Tl and Zn. Only As, Pb and Tl had an intake from wastewater-fed produce above 5% of the total intake. The intake of As, Pb and Tl from wastewater-fed produce contributed to 12.7, 9.5 and 26.1% of the total intake, respectively. Since the total intake of these elements was of no risk and the element contribution from waste water-fed products was low we conclude that the use of wastewater in aquatic production in Hanoi seems to be safe with respect to potentially toxic elements.

A comparison of the average Hanoi dietary element intakes to recommended values shows that the Hanoi diet is sufficient in most elements. However, the diet is insufficient in Ca, Cr, Fe, K and maybe Zn. Residents of Hanoi should supplement their diets with these elements. Dietary Cd intakes are relatively high, constituting 68-70% of the tolerable intake. The intake of Cd from other sources should therefore be mapped. The residents of Hanoi could improve the nutritional value and add to the safety of their rice-based diet through diversification with items like various leafy vegetables and animal-based foods in order to decrease Cd intake and increase Ca, Cr, Fe, K and Zn intakes.[47] Caution is required about approaches like single or multiple nutrient supplements without thorough risk assessment and communication. For some micronutrients biofortification of staple foods in an option, but even here reduction of phytate as a way of improving

Table 8. Daily dietary intake of non-essential and potentially toxic elements in international total diet studies given as µg (person*day)$^{-1}$ (without brackets) and µg (kg body weight * day)$^{-1}$ (in brackets)

Study	As(total)	Ba	Be	Cd	Ce	Li	Ni	Pb	Rb	Sb	Sr	Tl	U	Refer-ence
Hanoi 2007-2009	64.5 (1.29)	740 (14.8)	2.52 (0.0503)	34.1 (0.681)	4.77 (0.0954)	14.25 (0.285)	201 (4.02)	26.7 (0.534)	0.58 (0.0116)	1.675 (0.0335)	1000 (20)	1.385 (0.0277)	0.645 (0.0129)	Present study
United Kingdom 2006	(1.65-1.68)	(9.4)	-	(0.14-1.17)	-	-	(1.49-1.63)	(0.09-0.10)	-	(0.032-0.033)	(15.6)	(0.011-0.012)		29
Bombay 1991-1994	-	-	-	4.325	-	-	-	28.1	-	-	-	-	-	30
Korea 1998	38.5	-	-	14.3	-	-	-	24.4	-	-	-	-	-	38
Europe 1981-1999	38-286	-	-	10-30.2	-	-	-	17-280	-	-	-	-	-	39
Catalonia 2006	213.65	-	-	9.97	-	-	-	59.28	-	-	-	-	-	40
Tokyo 2000	-	-	-	15.9	-	-	-	6.74	-	-	-	-	0.587	31
Lebanon 2001	-	-	-	12.3	-	-	-	18.5	-	-	-	-	-	41
Japan 2002	-	-	-	26	-	-	-	21	-	-	-	-	-	32
Canary Islands	-	-	-	11.165	-	-	-	72.8	-	-	-	-	-	42,43
Sweden 1999	-	-	-	10	-	-	100	7	-	-	-	-	-	33
United States 1991-1996	27.9-95.5	-	-	8.9-12.8	-	-	-	-	-	-	-	-	-	35
Nothern Italy 2004	-	366.6	0.012	13.6	154.8	29.9	361.1	55.2	1370	-	1140	-	-	36
France	62.1	-	-	2.73	-	28.5	93.7	18.4	-	1.00	-	-	-	37

bioavailability needs evaluation against food-based approaches where phytase is part of traditional food technology and inositol content of the food is not compromised.[48]

ACKNOWLEDGEMENTS

We are grateful for the support provided by the National Institute of Occupational and Environmental Health (NIOEH), Vietnam. Especially, we want to thank Ms Thuy, Mr Duoc and Ms Hien at NIOEH for technical assistance with sample collection and pre-treatment of samples. Digestion and ICP-MS analyses of samples were conducted by the laboratory technicians Birgitte Boje Rasmussen and Maja H Wahlgren, Faculty of Life Sciences, University of Copenhagen.

AUTHOR DISCLOSURES

The study was carried out with financial support from the Council for Development Research (FFU), Danish Ministry of Foreign Affairs under project number 104.Dan.8.-887: “Metal accumulation and food safety in wastewater-fed aquatic production systems in Cambodia and Vietnam (Metsafe)”. The authors have no affiliation or have received funding which may pose a conflict of interest.

REFERENCES

1. Khan NC, Tue HH, Mai LB, Vinh LG, Khoi HH. Secular trends in growth and nutritional status of Vietnamese adults in rural Red river delta after 30 years (1976-2006). Asia Pac J Clin Nutr. 2010;19:412-6.
2. Thang NM, Popkin BM. Patterns of food consumption in Vietnam: effects on socioeconomic groups during an era of economic growth. Eur J Clin Nutr. 2004;85:145-53.
3. Dien LN, Thang NM, Bentley ME. Food consumption patterns in the economic transition in Vietnam. Asia Pac J Clin Nutr. 2004;13:40-7.
4. Khan NC, Ninh NX, Nhien NV, Khoi HH, West CE, Hautvast JGAJ. Sub clinical vitamin A deficiency and anemia among Vietnamese children less than five years of age. Asia Pac J Clin Nutr. 2007;16:152-7.
5. Pasricha S, Caruana SR, Phuc T, Casey GJ, Jolley D, Kingsland S, Tien NT, MacGregor L, Montresor A, Biggs B. Anemia, iron deficiency, meat consumption and hookworm infection in women of reproductive age in Northwest Vietnam. Am J Trop Med Hyg. 2008;78:375-81.
6. Nhien NV, Khan NC, Yabutani T, Ninh NX, Kassu A, Huong BTM, Do TT, Motonaka J, Ota F. Serum levels of trace elements and iron-deficiency anemia in adult Vietnamese. Biol Trace Elem Res. 2006;1111:1-8.
7. Nhien NV, Khan NC, Ninh NX, Huan PV, Hop LT, Lam NT et al. Micronutrient deficiencies and anemia among preschool children in rural Vietnam. Asia Pac J Clin Nutr. 2008; 17:48-55.
8. National Institute of Nutrition. General nutrition survey. Ministry of Health. Hanoi: Medical Publishing House; 2000.
9. Prom-u-thai C, Perkasem B, Cakmak I, Huang L. Zinc fortification of whole rice grain through parboling process. Food Chem. 2010;120:858-63.
10. Karunaratne AM, Amerasinghe PH, Ramanujam VMS, Sandsted HH, Perera, PAJ. Zinc, iron and phytic acid levels of some popular foods consumed by rural children in Sri Lanka. J Food Compost Anal. 2008;21:481-8.
11. Mai TTT, Hung NTK, Kawakami M, Kawase M, van Chuyen N. Micronutrient status of primary school girls in rural and urban areas of South Vietnam. Asia Pac J Clin Nutr. 2003;12:178-85.
12. Sigel A, Sigel H, Sigel RKO. Metal ions in toxicology: effects, interactions, interdependencies. Cambridge: The Royal Society of Chemistry; 2011.
13. Marcussen H, Joergensen K, Holm PE, Brocca D, Simmons RW, Dalsgaard A. Element contents and food safety of water spinach (Ipomoea aquatica Forssk.) cultivated with wastewater in Hanoi, Vietnam. Environ Monit Assess. 2008; 139:77-91.
14. Department of Science, Technology and Environment. General planning of environment in Hanoi in the period 2001-2010, Vol. 1. The real environmental situation of Hanoi. Hanoi: Peoples Committee of Hanoi; 2003. (in Vietnamese).
15. Marcussen H, Holm PE, Ha LT, Dalsgaard A. Food safety aspects of toxic element accumulation in fish from wastewater-fed ponds in Hanoi, Vietnam. Trop Med Int Health. 2007; 12 (Suppl 2):S34-S39.
16. Marcussen H, Dalsgaard A, Holm PE. Content, distribution and fate of 33 elements in sediments of rivers receiving wastewater in Hanoi, Vietnam. Environ Pollut. 2008a;155: 41-51.
17. Ali M, Quan N, Nam N. An analysis of food demand patterns in Hanoi: predicting the structural and qualitative changes. Technical bulletin no. 35. World Vegetable Center (AVRDC) publication no. 06-671. Shunhua: AVRDC; 2006.
18. Anh M, Ali M, Anh H, Ha T. Urban and peri-urban agriculture in Hanoi: Opportunities and Constraints for Safe and Sustainable Food Production. Technical bulletin no. 32, World Vegetable Center (AVRDC) publication no. 04-601, Shanhua: AVRDC; 2004.
19. World Health Organization. Guidelines for drinking water quality, Vol. 1, 4th ed. Malta: Gutenberg; 2011.
20. World Health Organization. GEMS/Food Consumption Cluster Diets. Global Environment Monitoring System – Food Contamination Monitoring and Assessment Programme (GEMS/Food). 2006. Available from: http://www.who.int/foodsafety/chem/gems/en/ (accessed Marts 2012).
21. Khan NC, Hoan PV. Vietnam recommended dietary allowances 2007. Asia Pac J Clin Nutr. 2008;17(Suppl 2):S409-S15.
22. National Academy of Sciences. Dietary Reference Intakes: RDA and AI for Vitamins and Elements. Food and Nutrition Board, Institute of Medicine. 2011a. [cited 2011/4/20]; Available from: http://fnic.nal.usda.gov/nal_display/index.php?info_center=4&tax_level=3&tax_subject=256&topic_id=1342&level3_id=5140 (accessed April 2011).
23. National Academy of Sciences. Dietary Reference Intakes: UL for Vitamins and Elements. Food and Nutrition Board, Institute of Medicine. 2011; Available from: http://fnic.nal.usda.gov/nal_display/index.php?info_center=4&tax_level=3&tax_subject=256&topic_id=1342&level3_id=5140 (accessed April 2011).
24. Codex Alimentarius Commisssion. Consideration of the codex general standard for contaminants and toxins in food. Codex Committee on food Additives and Contaminants, Codex Alimentarius Commission, 36th session, Rotterdam, The Netherlands, 22-26 March 2004. Rome: Joint FAO/WHO Food Standards Programme; 2003.
25. Joint FAO/WHO Expert Committee on Food Additives. Summery and conclusions. Seventy-second meeting. Rome: JECFA; 2010.
26. Lott JNA, Ockenden I, Batten GD. PA and phosphorous in crop seeds and fruits; a global estimate. Seed Sci Res. 2000; 10:11-33.
27. Lopez HW, Leenhardt F, Coudray C, Renesy C. Minerals and phytic acid interactions: is it a real problem for human nutrition? Int J Food Sci Tech. 2002;37:727-39.

28. World Health Organization. Trace elements in human nutrition and health. Geneva: WHO; 1996.
29. Rose M, Baxter M, Brereton N, Baskaran C. Dietary exposure to metals and other elements in the UK total diet study and some trends over the last 30 years. Food Addit Contam. 2010;27:1380-404.
30. Tripathi RM, Raghunath R, Krishnamoorthy TM. Dietary intake of heavy metals in Bombay city, India. Sci Total Environ. 1997;208:149-59.
31. Aung NN, Yoshinaga J, Takahashi JI. Dietary intake of toxic and essential trace elements by the children and parents living in Tokyo metropolitan area, Japan. Food Addit Contam. 2006;23:883-94.
32. Maitani T. Evaluation of exposure to chemical substances through foods-exposure to pesticides, heavy metals, dioxins, acrylamide and food additives in Japan. Food Addit Contam. 2004;50:205-9.
33. Becker W, Jorhem L, Sundström B, Grawé KP. Contents of mineral elements in Swedish market basket diets. J Food Comp Anal. 2011;24:279-87.
34. Iyengar GV, Kawamura H, Parr RM, Miah FK, Wang J, Dang HS, Djojosubroto H, Cho S, Akher P, Natera ES, Nguy MS. Dietary intake of essential minor and trace elements from Asian diets. Food Nutr Bull. 2002;23:124-8.
35. Egan SK, Tao SSH, Pennington JAT, Bolger PM. US food and drug administration's total diet study:intake of nutritional and toxic elements, 1991-96. Food Addit Contam. 2002;19:103-25.
36. Turconi G, Minoia C, Ronchi A, Roggi C. Dietary exposure estimates of twenty-one trace elements from a total study carried out in Paria, Northern Italy. Br J Nutr. 2009;101: 1200-8.
37. Leblanc J, Guérin T, Noël L, Calamassi-Tran G, Volatier J, Verger P. Dietary exposure estimates of 18 elements from the 1st French total diet study. Food Addit Contam. 2005; 22:624-41.
38. Lee H, Cho Y, Park S, Kye S, Kim B, Hahm T, Kim M, Lee JO, Kim C. Dietary exposure of the Korean population to arsenic, cadmium, lead and mercury. J Food Comp and Anal. 2006;19:S31-37.
39. Nasreddine L, Parent-Massin D. Food contamination by metals and pesticides in the European Union. Should we worry? Toxicol Lett. 2002;127:29-41.
40. Marti-Cid R, Llobet JM, Castell V, Domingo JL. Dietary intake of arsenic, cadmium, mercury, and lead by the population of Catalonia, Spain. Biol Trace Elem Res. 2008;125: 120-32.
41. Nasreddine L, Hwallla N, Samad OE, Leblanc JC, Hamze M, Sibiril Y, Parent-Massin D. Dietary exposure to lead, cadmium, mercury and radionuclides of an adult urban population in Lebanon: A total diet study approach. Food Addit Contam. 2006;23:579-90.
42. Rubio C, Hardisson A, Reguera JI, Revert C, Lafuente MA, González-Iglesian T. Cadmium dietary intake in the Canary Islands, Spain. Environ Res. 2006;100:123-9.
43. Rubio C, González-Iglesias T, Revert C, Reguera JI, Gutiérrez AJ, Hardisson A. Lead dietary intake in a Spanish population (Canary Islands). J Agric Food Chem. 2005;53:6543-9.
44. Tamaki S, Frankenberger WT. Environmental biochemistry of arsenic. Rev Environ Contam Toxicol. 1992;124:79-110.
45. Schoof R, Yost L, Eickhoff J, Crecelius E, Cragin D, Meacher D, Menzel D. A market basket survey of inorganic arsenic in food. Food Chem Toxicol. 1999;37:839-46.
46. World Health Organization. Thallium and thallium compounds. Health and safety guide no. 102. International programme on chemical safety (IPCS). Geneva: World Health Organisation; 1996. [accessed March 2012]; Available fromhttp://www.who.int/foodsafety/chem/gems/en/index1.html.
47. Wahlqvist ML, Specht RL. Food variety and biodiversity: Econutrition. Asia Pac J Clin Nutr. 1998;7:314-9.
48. Bouis HE, Welch RM. Biofortification-A sustainable agricultural strategy of reducing micronutrient malnutrition in the global south. Crop Sci. 2010;50:S20-S32.

Original Article

Dietary exposure to essential and potentially toxic elements for the population of Hanoi, Vietnam

Helle Marcussen PhD[1], Bodil H Jensen MSc[2], Annette Petersen MSc[2], Peter E Holm PhD[1]

[1]*Department of Plant and Environmental Sciences, Faculty of Science, University of Copenhagen, Frederiksberg C, Denmark*
[2]*Department of Food Chemistry, National Food Institute, Technical University of Denmark, Søborg, Denmark*

越南河內居民之必需及潛在毒性元素的飲食暴露

在快速開發之東南亞國家如越南，對於其飲食攝取必需及潛在毒性元素的所知有限。在亞洲，鐵和鋅缺乏是一項眾所周知的問題，部分原因來自於米飯是構成飲食的主體。但飲食習慣正改變中，需要獲取更多新知，俾有關當局能給予適當之飲食建議。本篇研究的目的在於確立必需和潛在毒性元素之總膳食攝取量，並評估河內市一般飲食之營養品質及食品安全風險。將所有食物定義成 22 項食物類別，每一食物類別各收集 14 個樣本，樣本主要來自市場和/或超級市場，時間為 2007-2009 年間。空心菜、水芹菜、水田芥、水含羞草、池水魚，這些食物通常會藉由汙水養殖系統來生產。因此，這些樣本之收集包含來自市場與汙水養殖系統。研究結果顯示，大部分的河內市食物中只含有極少或無危害風險之毒性元素。再者，來自汙水養殖的產品中，其所含的元素量極低，關於潛在毒性元素之含量亦不構成問題。將河內市飲食中必需元素之平均攝取量與需要量相比較，顯示河內飲食所含元素大部分皆足夠。然而，飲食中鈣、鉻、鐵、鉀及鋅可能不足，為此，加強飲食多樣性及生物強化或許可提供解決之道。

關鍵字：必需元素、毒性元素、飲食攝取、飲食調查、河內市